On-Farm Carbon Sequestration
Can Farmers Employ it to Make Some Money?

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Abstract

Increase in the atmospheric levels of greenhouse gases (GHG) is believed to have caused recent changes in the Earth's climate, commonly known as global warming. Agriculture can contribute to the reduction in GHG emissions through what is known as carbon sequestration, which has gained attention in recent years as it might become a source of additional income to farmers. In this paper, we review the prospects for farmers making money by adopting practices that sequester carbon. We review current US mitigation policy, the comparative potential of carbon sequestration as a GHG mitigation alternative, and recent developments in the US carbon market. We show that currently the prospects for making money may be limited to only a few farmers. The situation might change with the change in US mitigation policy.

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Concern about human induced climate change has increased in recent years with substantial attention being focused on options to mitigate climate change. Scientists believe that the atmospheric build up of greenhouse gas[1] (GHG) concentrations is causing the climate to change (Intergovernmental Panel on Climate Change – IPCC, 2001). Further, they assert that continuing levels of GHG emissions will lead to future climate change. Carbon dioxide is the largest of the GHGs in both emissions and concentration. In the U.S. carbon dioxide emissions largely arise from two sources - electric power generation and petroleum product usage that, according to an EPA estimate, contributed 84% of 1999 emissions. Reducing net carbon emissions to the atmosphere is increasingly being considered as a way of addressing the climate change problem.

Direct emission reduction is the obvious strategy to reduce net emissions but involves modifying key elements of the American way of life as it relates to energy consumption (heating/cooling, traveling, etc.). An alternative strategy involves enhancing absorption of atmospheric carbon into vegetation with subsequent storage in soils and long lived plants/trees/wood products. Such a process is commonly called carbon sequestration.

Carbon sequestration is an appealing alternative as it allows continued energy consumption, while potentially benefiting farmers and the environment. As a result, the sequestration alternative has attracted interest of researchers, energy industry, policy makers, and farmers alike. This paper discusses the sequestration situation focusing on the current potential for farm income enhancement. In particular, we will overview the questions:

- Why this is a possibility -- The climate change/ GHG emission/ concentration situation

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[1] The term Greenhouse gas refers a group of gasses that adds to the reflective and heat trapping characteristics of the atmosphere. The name Greenhouse Gases is given due to the similarity of effects that GHG concentrations have relative to the effects of Greenhouse glass on the climate within a Greenhouse. In particular the GHGs are largely transparent to the Sun's energy coming to the Earth, but allow less of the solar energy reflected off of the earth's surface to be reflected into space trapping additional heat. As a result, the Greenhouse theory argues that the Earth's overall temperature increases when the concentration of greenhouse gases increases.

- What the societal and farm level options are for GHG emission mitigation
- Who might pay for carbon sequestration or other GHG offsets?
- The existing status of the carbon market in the US
- The prospects for farmers' earning additional income through sequestration or other activities offsetting GHGE.

Climate Change and Human Activity

Temperature records for the last 100 years show that global average surface temperatures have increased by 0.6^{o}C (IPCC 2001), with large increases registered at the end of the century (US National Assessment, 2001). As scientists have explored the causes for such warming, they arrived at GHG atmospheric concentration as an important explanatory phenomenon. Figure 1 (drawn from the US National Assessment, 2001) illustrates the observed temperature increase in relation to the observed increase in atmospheric CO_2 concentration and the observed increase in emissions. Such observations coupled with other scientific theories have led to the assertion that the observed increase in global temperature has been largely caused by the increase in GHG concentrations, which in turn was caused by the increase in GHG emissions. Furthermore, a large international scientific group (IPCC 2001) asserts that, if not checked, the rapid pace of GHG emissions will lead to a further rise in the global temperature. Projections are that the increase in global temperature may range 3 to 5^{o}C by 2100.

The expansion in GHG emissions has largely been the product of economic development over the last two centuries mainly involving deforestation, land use change, petroleum usage and coal-based electricity generation. Recent atmospheric GHG concentration levels are substantially higher than those in the observable fairly distant past. For example, an examination of the air bubbles trapped in the Antarctic ice cores, whose record goes as far back as 160,000 years, shows that the highest level of CO_2 and CH_4 concentrations have been, respectively, 300 ppmv (parts per million by volume) and 0.7 ppmv; in contrast, their levels in 1995 were found to be 360 ppmv and 1.7 ppmv (Harvey).

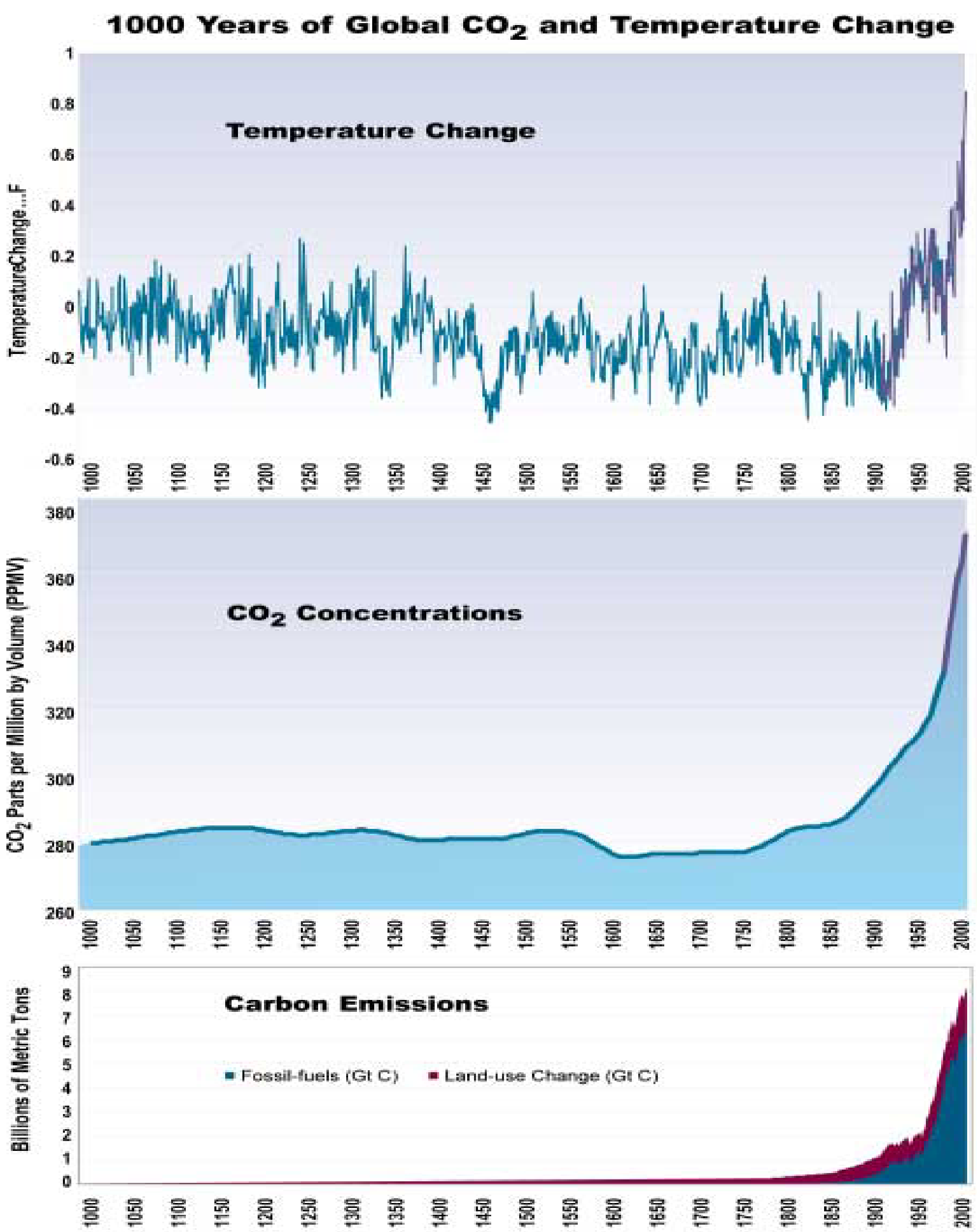
Climate change, if it continues, is likely to have an effect on life on the planet Earth. Observational evidence, including recent glacial melting, altered species' migration, and unusually hot summers and warm winters portend the effects of future climate change. Numerous studies have been conducted on climate change impact on various facets of human life including agriculture, weather pattern, and wildlife. The second report of the IPCC lists a number of potential future effects:

- agriculture in cold regions may benefit, while that in warm regions may suffer
- sea level may rise due to glacier melting caused by higher temperature

- extreme weather events like droughts and hurricane may become more frequent and more intense

- wildlife may migrate from warmer to colder regions to adapt to warming

Figure 1. Global temperature, carbon emissions, and atmospheric CO_2

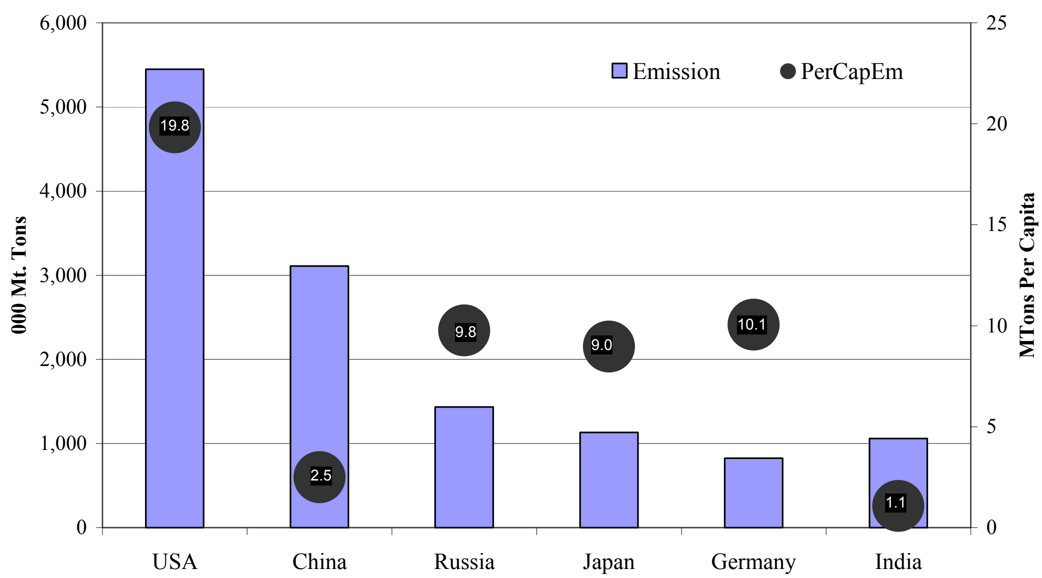


Source: US National Assessment.

Climate Change Mitigation

The concern over possible consequences of climate change and it's links to GHG emissions have led many in society to propose actions to slow down GHG emissions. The first major international step towards this end was the 1992 formation of the United Nations Framework of Convention on Climate Change with the stated goal of atmospheric GHG concentration stabilization. Subsequently, in 1997 Kyoto Protocol was established to set quantitative emission reduction targets. Under the Protocol, countries were assigned emission reduction targets according to their contribution to GHGE. Major contributions to GHGE are made by countries with higher level of industrial activity as shown in Figure 2 where the US is shown to have the largest share of emissions both in total and on a per capita basis.

Figure 2. **Total and Per Capita CO2 Emission**



Source: The Little Green Data Book - 2002, The World Bank

Within the Kyoto Protocol, U.S. emissions were to be reduced to 7 percent below 1990 levels by 2008-2012. In 2002, the U.S. stated it would not sign the Protocol but has subsequently stated domestic policy goal of an 18% reduction in GHG emissions per dollar of gross domestic product by 2012. Such actions portend a need for net GHG reductions.

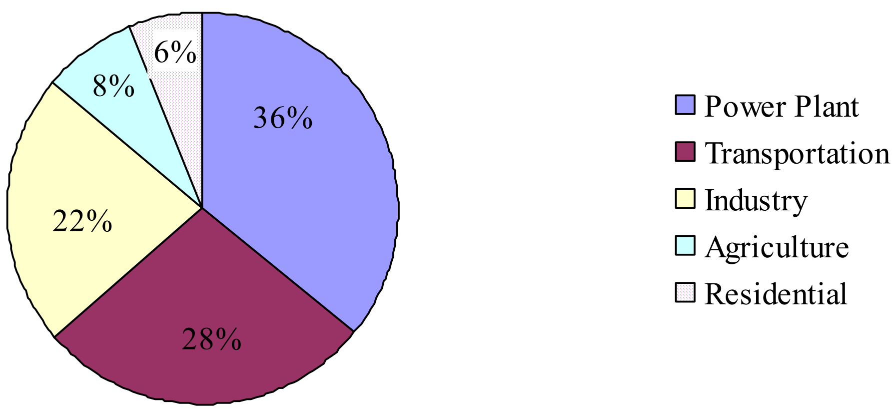
Substantial changes in human technologies are necessary to reduce emissions. However, a number of the currently available alternative technologies are expensive, which motivated many economic and policy dialogues on achieving mitigation objectives with minimum costs. A cap and trade offset market has been widely discussed where emitters are allocated rights to particular emission levels and they can only exceed those rights if they buy rights from others (Ierland, Gupta, and Kok, 2003, p 106; Stavins, 2002). This allows emitters facing high emission reduction costs to buy emission rights from those who can reduce emissions and/or produce emission offsets at lower costs. Soil based sequestration can be pursued to offset emissions by reducing carbon from the atmosphere.

Who Might Buy in a GHG Offset/Carbon Market?

A buyer of carbon offset can be any entity needing to reduce/offset its GHGE. For example, a power plant facing an emission cap might be looking for ways to offset its emissions that are over and above certain limit. The objective of a buyer would be to acquire offset credits at a lower cost than it would cost them to alter operations so emissions were reduced.

The largest buyers are likely to be the largest emitters. The major U.S. sources of GHG emissions are electric utilities (power plants), transportation, and the manufacturing industry, as shown in Figure 3.

Figure 3. Carbon Emission Sources in US



Source: EPA - U.S. GHGE Inventory 2003

Who Might Supply in a GHG Offset/Carbon Market?

The supply of carbon offsets may come from various sources. GHG emitters may alter their practices that cause lower GHG emissions, reduce their fuel consumption, or switch to alternative fuels (for example, from coal to natural gas or biofuel). In addition, a number of forms of sequestration may be pursued.

The two fundamental sequestration approaches involve mechanical and biological sequestration. Mechanical sequestration involves the capture or assembly of carbon then its subsequent injection into geological formations or the ocean. Biological sequestration involves actions to enhance retention of carbon in soils, vegetation/trees and water bodies.

The agricultural aspect of GHG mitigation largely involves soil sequestration, establishment of new forests, and some emission reduction actions (involving manure management, fuel conservation, fertilization management, and animal feeding (McCarl and Schneider, 2001). Soil Sequestration can be enhanced through a combination of land management and land use practices (Lal et al., 1998). Land management may include shifting from deep tillage to reduced or no tillage, and changes in crop rotation. Land use may include converting cropland to grasslands or forests.

The Current Prospects for Farmers' Making Money

When society decides it is time to reduce GHG net emissions, the prospects will arise for farmers' to earn additional income through carbon sequestration. The strength of that opportunity depends on the status of the market, the competitiveness of farmers in producing carbon offsets, and the role of government. We briefly review these factors.

Existing Status of the US GHG Market

There are two fundamental ways that farmers might be paid for sequestration. The first and traditional method is through some form of practice subsidy including programs such as CRP and EQIP that pay farmers to retire land or alter practices. The second involves emergence of a trading market that would allow private buyers to contract with private sellers. The subsidy process is well understood so will not be discussed here although we should note that it probably offers the largest current potential for U.S. farmer income enhancement.

Turning to the private market possibility, the strength of that market is strongly tied to the US policy for GHGE mitigation. The Bush administration announced in 2002 that it would not ratify the Kyoto Protocol. The administration has, however, announced it's intent to reduce GHGE intensity – a measure of emissions per unit of economic activity. The administration has set a target of 18 percent reduction in GHGE intensity over the next 10 years. This level of emission intensity reduction has been estimated to amount to about 1/6th of the emissions reduction required under the Protocol, where the Protocol itself is 1/20th the progress needed to achieve atmospheric concentration stabilization. Simultaneously, a number of states including Oregon, Wisconsin, Indiana, New Hampshire are taking actions to restrict GHG emissions (Rewey and Brown, 2001). For example, Oregon has put in place laws that set stricter standards for new power plants regarding their energy efficiency. New Jersey developed a Greenhouse Action Plan that calls for increased inspection of vehicular emission and more recycling.

Regardless of policy, it is fair to say that there is no widespread emission reduction enforcement in place in the US. Nevertheless, current policy debates, state level mitigative actions, and the fact that various countries around the world have ratified Kyoto Protocol point to the possibility of a carbon constrained future. This has raised concerns on the behalf of emitters who now face uncertainty as to whether GHG emission limits will be imposed in the next 10-20 years. Furthermore, multinational corporations face emission caps for their operations in Kyoto ratifying countries (for example, Canada, UK, Germany, and Mexico).

This prospective and actual emission caps place business assets at risk. For example, assuming that an eventual cap of 7% below 1990 levels is imposed and that energy use growth continues until the time that the cap is imposed, it is not unreasonable to think that industry faces a substantial chance of needing to operate in a world where by 2010 emissions need to be 15% or so smaller than they would have been under business as usual. Assuming that the emissions are proportional to total output this would put at risk 15% of gross sales, facilities etc.

The magnitude of the risk caused by possible implementation of GHGE limits has drawn industry attention. Many firms have started the quest to discover and even begin implementation of ways to reduce GHGE in an economically sound manner. Virtually all petrochemical and electric power generating firms now have offices with titles involving climate change or greenhouse gas emissions charged with trying to develop, and sort out an array of possible business responses for GHGE management. Sequestration is a major option on the table.

This has led to what can be termed a *niche carbon market*, where emitters and mitigaters have signed limited scope contracts for producing carbon offsets. The main motivation of the participants in this niche is a mixture of

- response exploration where firms are questing to develop strategies to address future possible emission caps

- environmental citizenship where firms wish to be responsible environmental actors possibly for advertising purposes

- business venture exploration where firms desire to see if they can develop future salable capabilities for GHG emission management

- cost reduction where firms wish to tie up low cost alternatives in anticipation of future emission caps

On the supply side, farmers who are participating are either in close proximity to the niche market and have been offered participation options or are venturing to explore new opportunities anticipating they will be low cost producers of offsets or that they can be paid for GHG offsetting practices they have already undertaken.

There have been two ways that the niche markets have been operating.

- Direct Contracts: Some energy companies have directly approached agricultural producers to generate carbon offsets. For example Reliant Energy, a Houston-based energy company, is funding planting of over 150 thousand trees in an effort to capture an estimated 215 thousand tons of carbon dioxide from the atmosphere, generating "carbon credits" that will be retained by Reliant (http://www.ewire.com/display.cfm/Wire_ID/1557). Similarly GEMCO Inc., a Canadian energy company, has contracted hog producers in the US Midwest for carbon offsets.[2]

- The Chicago Climate Exchange (CCEX): A fledgling trading operation is emerging with this name that is based on a voluntary association of a number of emitters and offset suppliers. In that association, the participants sign contracts to reduce net emissions directly or through trading. The CCEX has set up guidelines for soil carbon participation. Namely, an entering group has to represent a minimum of 10,000 tonnes of carbon, has to commit to 4 years of continuous conservation tillage, and must not plant soybeans for more than two years. No requirements are imposed on how that land was used in the past. Participating farms must have at least 250 acres that will be inspected by the CCEX to ensure that conservation tillage is practiced. Farmers will be paid at the rate of 0.15 ton of carbon per acre. Carbon offsets generated from grassland may also get credit at the rate of 0.21 ton of carbon per acre, provided grasses are planted after January 1, 1999. There have been an array of price levels at which the exchange of carbon took place at the CCEX. The auction prices as of October, 2003 have ranged $1.84 - $9.9 per ton carbon, with a weighted average of $3.6 per ton carbon.[3] Under the CCEX rating and weighted average of auction prices, farmers may get $0.49 an acre for the tillage change and $0.74 an acre for grass plantation.

The above discussion shows that due to recent developments in policy arena in the US and around the world, emitters anticipate carbon regulatory regime, while farmers hope for earning income by participating in GHG emissions abatement. Presently, however, buying and selling activities in the carbon market are indicative of exploratory behavior of buyers and sellers rather than economic opportunities. As the market develops, economics of sequestration would start to play a greater role, which raises the question whether or not farmers are competitive suppliers of carbon offsets.

Are Farmers Competitive Suppliers of Carbon Offsets?

As shown in Figure 3, more than 80 percent of GHG emissions come from three sectors - energy production, transport, and industry. Hence, any mitigation plan would first focus these major emitting sources. A variety of alternatives may be pursued including switching fuel sources (for example, coal to natural gas and biofuel), increased mass transit usage, improved energy efficiency, and mechanical/biological carbon

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[2] Hog producers can produce carbon offsets by reducing methane emissions from alternative manure handling, where methane emissions are then credited as equivalent carbon offsets.

[3] It is important to note that currently there is no daily trading taking place at CCEX. So far there has been only one auction that took place on September 3, 2003. The auction prices mentioned are those reported by the CCEX for the September trading. Future prices are likely to change.

sequestration. Under trading, a source of GHGE mitigation must be competitive in order to find its place in the carbon market.

The competitive potential of farmers in supplying GHG offsets will be determined by what it might cost to sequester and sell the offsets. A critical factor is the income change when shifting from non-sequestering alternatives. For example, shifting from conventional tillage to conservation tillage is a sequestration alternative. The loss of income, if there is any, would form the basis of sequestration cost. As loss of income will differ across different farms, the cost of sequestration would be different for different farmers. Paustian et al. (2001) show that sequestration cost under the tillage change may vary from $0 a ton of carbon to over $300 a ton of carbon for farmers in Iowa. Several other studies computed how much carbon can be sequestered for a given carbon payment, which is an implicit indicator of the cost of carbon sequestration. Figure 4 shows results from McCarl and Schneider (2001), while Table 1 provides summary estimates from some of the studies.

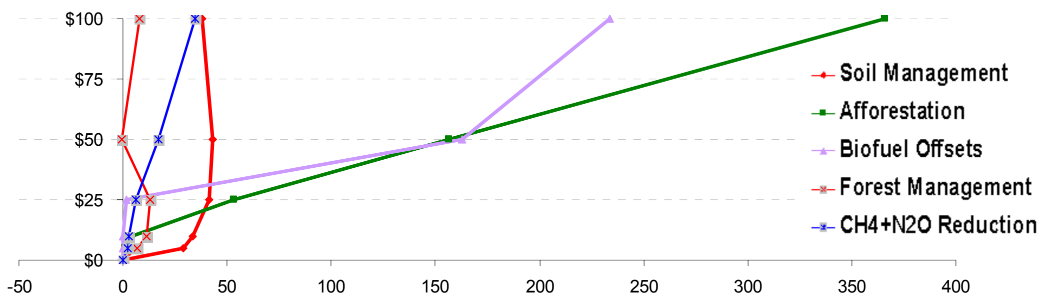
McCarl and Schneider (2001) show that land management practices (mainly tillage change and converting cropland to grassland) are competitive at relatively low offset prices, about $25 per ton of carbon, showing that not only altering land management practices may cheaply generate carbon offsets but also that the potential may not be great as an independent calculation would reveal (such as the 140 million tons in Lal et al., 1998). Namely, the potential offsets from forestry and bio-fuel production are substantially greater per acre but involve greater opportunity costs and thus, only enter at higher prices. Nevertheless, other alternatives put an upper limit on agricultural soil carbon that is lower than if it were considered independently (see McCarl and Schneider, 2001 for details).

The studies conducted on sequestration cost have mostly focused on developing a supply curve for carbon sequestration. In other words, their intent was to estimate how much carbon might be sequestered against different carbon payments concluding that as carbon payment was raised more farmers would switch to practices that sequester carbon, which showed farmers had different payment threshold (alternatively, cost) for switching to practices that sequester carbon. Therefore, at low carbon prices, as they are presently, only low cost farmers might be competitive suppliers of carbon and be able to benefit from participating in the carbon market. However, the price of carbon offsets may increase with the shift in US mitigation policy towards tighter emission control. For example, Edmonds et al. estimate per ton cost of meeting the Kyoto Protocol target for the US. They show that if the US, acting on its own, were to meet its Kyoto Protocol target emission reduction, the cost may be as high as $250 per ton carbon. With international trading of carbon offsets, however, the cost may fall to around $25 per ton carbon. Estimates from Edmonds et al. are based on an overall GHG emissions reduction including agriculture, fuel substitution, and energy production/consumption.

Other concerns regarding permit sales through sequestration

There are several additional factors that might influence the desirability of a sequestration opportunity to farmers. These include altering operations, middle man costs, possible discounts, longer term commitments, and measurement costs.

Figure 4. Competitive Potential of Soil Based GHGE Mitigation Practices



Source: McCarl and Schneider (2001)

Table 1. Estimates of Carbon Sequestered for Given Carbon Payments

Study	**Sequestration Strategy**	**Payment**	**Carbon Seq. (Mil. MT)**
Paustian et al.	Tillage	$90	1.7
Antle, Capalbo, and Mooney	Tillage and grassland	$30	11
House et al.	Tillage, forestry, and grassland	$25	35
Faeth and Greenhalagh	Tillage, pasture, and fertilizer	$27	40

<u>Altering Operations</u>: Sequestering carbon often involves farmers altering technology or management. This can lead to altered equipment requirements, increased management demands, increased risk especially during early stages of use, and educational needs. For example, shifting from conventional tillage to reduced tillage farmers will need new equipment and may experience increased pest and weed problems requiring new treatment regimes possibly with increase crop damage (IPCC, 2001- p 758).

<u>Middleman Costs</u>: The amount of carbon sequestered by a farmer will be small compared to buyers' needs. On average, a tillage change may sequester 1/4 ton of carbon per acre annually (West and Post, 2001). In turn, a farmer owning 400 acres of land would supply about 100 tonnes of carbon. In contrast, the buyers' want substantially larger volumes.

For example, Chicago Climate Exchange trades now require a minimum contract of 10,000 tonnes of carbon would require at least a hundred farmers with 400 acres. Thus, there is a role for an aggregating middleman that gathers farmers and represents them to a buyer. Middlemen will introduce a wedge between the price received by farmers and that paid by buyers consisting of the middleman's commission.

Market Discounts: Farmers may not be able to sell all the carbon they store as discussed in McCarl, Butt and Kim (2003). In the more general market place, discounts may arise to correct for

- actions that would have occurred in the absence of a carbon program (commonly called *additionality*), which also means that that there is a risk to early start in generating offsets as they may be treated as not being *additional* meaning that farmers many not get full credit for their offsets

- actions in other regions that offset gains made in this region, (commonly called leakage)

- uncertainty in the amount of carbon obtained

- differences in the way the offsets are stored versus emissions offset (commonly called permanence, volatility or saturation)

Long Term Commitment: The nature of sequestration dictates that sequestering practices must continue, or else the carbon stored in soils would revert back to the atmosphere (Carmer and Field, 1999). Presently at CCX, sequestration based offsets require a four year commitment. Once an emission cap is in place, the length of contract is only likely to increase. Hence, farmers signing carbon contracts may be obligated to permanently follow sequestration practices regardless of the future income that they might get from other alternatives. This raises property rights and risk issues. For example,

- If a farmer sold his land under sequestration contract how will the new owner be made to honor the contract?

- If the farmers sell sequestration rights will they be able to bring new lands into production without buying emission rights

- Will sale also cause one to have to get permits if emissions are increased by increasing fertilization, adopting irrigation, expanding livestock based emissions or other actions?

- How will liability be assigned if one is unable to meet an obligated sequestration target?

- Will there be any recourse if weed treatment costs increase due to long term development of herbicide resistance?

Measurement Costs: Unlike traditional farm produce, the volume of carbon cannot be directly observed as it is inherent in the farm soils. Hence, a mechanism for verifying the quantity of carbon sequestered is needed. The mechanism might include collecting soil samples and measuring the amount of soil carbon on farmers' land. Either buyer or farmers would have to incur the cost of measuring carbon, which ultimately means an abrasion of farmers' payoff.

Role of Government

The activities that stimulate carbon sequestration are commonly in harmony with resource conservation objectives like reduced erosion and improved water quality. Consequently, the government may have an interest in promoting carbon sequestration. Hence, it may bear a part of the cost of producing soil based carbon offsets improving their competitiveness against non-soil based carbon offsets. Though, there has been an active consideration of carbon sequestration in the US farm policy arena, no tangible, well funded program is in place yet.

Conclusion

Climate of the planet Earth is believed to be changing and the cause is alleged to be the high level of emissions of GHGs including carbon dioxide. Agriculture can contribute to the reduction in emissions through what is known as carbon sequestration comprising practices that capture the consequences of emissions from the atmosphere and store in the soil in the form of carbon. The interest in carbon sequestration as a source of emissions mitigation is increasing. Carbon sequestration is attracting attention from farmers and policy makers as it might become a source of additional income to farmers.

The current carbon market reveals that current prospects for farmers' making money from sequestration are limited. Farmers who have participated are generally exploiting some small market niche. At the existing carbon offset prices, as reported by CCEX, farmers may earn $0.49 per acre for practicing conservation tillage and $0.74 per acre for planting grasses along with a number of conditions. Also, farmers are at risk by participating in the carbon market early on.

The prospects for farmers earning additional income through carbon sequestration may become favorable if the US government enforces a GHGE reduction plan that stimulates higher market prices and/or introduces well funded programs that share part of the carbon sequestration cost.

References:

Antel, J., Capalbo, S., and Mooney, S. "An Integrated Assessment Approach to Modeling Soil C Sequestration: What Have We Learned and Future Directions?" Prepared for USDA/EPA GHG Modeling Forum, Shepherdstown, WV, October 2, 2001.

Cramer, W. and Field, C. B. "Comparing Global Models of Terrestrial Net Primary Productivity (NNP): Introduction", *Global Change Biology,* 5(1999), 3-5.

Edmonds, J.A., MacCracken, C.N., Sands, R.D., and Kim, S.H. Unfinished Business. The Economics of the Kyoto Protocol. US Dept. of Energy, September 1998. http://www.pnl.gov/globalchange/pubs/gtsp/kyoto_paper_98.pdf

Harvey, L.D.D. *Climate and Global Environmental Change.* Prentice Hall, Toronto, 2000.

House, R., Lewandrowski, J., Peters, M. and Jones, C. "Modeling Carbon Emissions Charges and Carbon Sequestration Payments in U.S. Agriculture: A Description of the USMP Model." Presented at Forestry and Agriculture Greenhouse Gas Modeling Forum. Shepherdstown WV, October 1-3, 2001.
http://foragforum.rti.org/documents/ConferWV_USMP_Model.doc

Jepma, C. J. and Bandsma, J. "Policies and Measures in International Policy: Price vs. Quantity." *Issues in International Climate Policy – Theory and Policy*. E. C. Ierland, J. Gupta and M.T.J. Kok, eds., Edward Elga Pub. Inc., Massachusetts, 2003.

Intergovernmental Panel on Climate Change (IPCC). *Climate Change: The IPCC Third Assessment Report - Impacts, Adaptations, and Vulnerability.* J.J. McCarthy, O.F. Canziani, N.A. Leary, D.G. Dokken, and K.S. White, ed. Cambridge, MA: Cambridge University Press, 2001.

________________. *Climate Change: The IPCC Second Assessment Report, Volume 2: Scientific-Technical Analyses of Impacts, Adaptations, and Mitigation of Climate Change.* R.T. Watson, M.C. Zinyowera, and R.H. Moss, ed. Cambridge, MA: Cambridge University Press, 1995.

Lal, R., J. M. Kimble, R. F. Follett, and C. V. Cole. *The Potential of U.S. Cropland to Sequester Carbon and Mitigate the Greenhouse Effect*, 128 pp., Sleeping Bear Press Inc., Chelsea MI, 1998.

McCarl, B.A. and Schneider, U.A. "The Cost of Greenhouse Gas Mitigation in U.S. Agriculture and Forestry", Science, 294 (December, 2001), 2481-82.

McCarl, B. A., Butt, T.A., and Kim, M. "How Much Would Carbon Cost a Buyer?" Department of Agricultural Economics, Texas A&M University, College Station, Texas. 2003.

Paustian, G.R., Kurkalova, L.A., Babcock, B.A. and Kling, C.L. "The Efficiency Of Sequestering Carbon In Agricultural Soils." *Contemporary Economic Policy*, 19(April 2001): 123-124. http://www.card.iastate.edu/publications/texts/00wp246.pdf

Rewey, C. and Brown M. *Greenhouse Gas Reduction: State Case Studies.* National Conference of State Legislatures, Washington, 2001. www.ncsl.org/programs/esnr/ghgr/

Stavins, R.N. "Lessons From The American Experiment with Market-Based Environmental Policies." *Harnessing the Hurricane: The Challenge of Market-Based Governance*. J. Donahue and J. Nye, eds. Brookings Institution Press, 2002.

U.S. Global Change Research Program (USGCRP). *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change* 2001. Available at: http://www.usgcrp.gov/.

West, T.O. and W.M. Post, "Soil Organic Carbon Sequestration Rates by Tillage and Crop Rotation. A Global Analysis. " *Soil Society of America*, 66(2002), 1930-46.